CHAPTER 3. STRATEGIC APPROACH FOR RESTORATION

The change from historic to existing conditions in the Sammamish River Corridor discussed in the previous two chapters describe a system with very significant constraints on the ecological functions the area can be expected to provide. Prior to the lowering the level of Lake Washington and channelization and dredging of the river, the Sammamish River Corridor was a vast wetland complex, which is almost entirely gone today. The Seattle metropolitan area now exists within and surrounding the changed corridor. The historic conditions cannot be re-established. However, the Sammamish River Corridor still performs important ecological functions, especially as a migratory link between other habitats. Most obviously, it is a link between Lake Washington and Lake Sammamish, but it also links numerous tributaries and upland habitats with each other and with the lakes. Many species in addition to salmon use it as a critical migratory corridor. The fundamental goal of the Action Plan is to make the Sammamish River Corridor a strong link, rather than a weak one, in this larger ecosystem.

The Action Plan recommends the following overarching strategy to meet this goal with the following key elements:

- *Restore riparian areas throughout the river corridor* by regrading the river's banks and planting them with native vegetation to provide shade, cover and enhanced habitat and habitat-forming processes for all native fish and wildlife.
- *Create and enhance pools in the river channel* to provide cool-water refuge and cover, particularly for migrating adult salmon; design the pools to be sustained over time by the river's hydraulics.
- *Explore engineered solutions to cool the river upstream of Bear Creek* where thermal stress for migrating adult salmon is greatest.
- *Protect all major tributaries to the river*, particularly Bear Creek, as sources of cool water for the river and as habitat for other life stages of fish and wildlife using the river.
- *Apply adaptive management systematically across jurisdictions*, monitor projects closely and compare them to each other and to baseline conditions, to identify features of greatest value to include in future projects as progress is made toward river-wide restoration.

These strategies serve multiple purposes. However, a driving concern of the Action Plan is to reduce the stress of high summer water temperature on migrating salmon. The temperature modeling conducted by King County is included as Appendix B and describes a detailed review of some of the potential options available to address this concern. Its findings provide an important foundation for the strategies discussed in this chapter. Additionally, there are other problems in the corridor that should continue to be addressed, but are generally given lower priority than the above listed strategy. They are briefly described at the end of this chapter.

RESTORE RIPARIAN AREAS THROUGHOUT THE SAMMAMISH RIVER CORRIDOR

Healthy riparian areas could provide crucial shade to reduce solar heating of the Sammamish River. Improvements to riparian areas are also fundamental to maximizing the river's capacity to serve as a migratory corridor for birds and other wildlife. As discussed in Chapter 2, riparian areas in the Sammamish River Corridor are currently in extremely poor condition. The river is completely cut off from its former oxbows and side channels and has only a few connections with riparian wetlands, primarily in Reaches 1, 3 and 6. Only a few locations along the river have native or even partly native plant communities. Dredging for flood control in the 1960s was either the direct cause, or indirectly supported other actions that seriously aggravated most of these conditions. The maintenance standards of the Corps, which have required minimizing woody vegetation to maintain the river's flood conveyance capacity, have resulted in continuing degraded conditions. In recent years, the Corps has re-evaluated some of these requirements, partly in response to changes in environmental regulations, including the listing of Puget Sound chinook salmon under the Endangered Species Act. Maintaining flood conveyance and a healthy riparian area are not mutually exclusive. Sloping back the river's banks prior to revegetation improves riparian habitat value for both fish and wildlife and increases channel conveyance. Perhaps the greatest advantage for restoration of the Sammamish River is that approximately 70 percent (length) of the riparian area on both banks is publicly owned.. The public owns or has conservation easements on at least one bank of an additional 20 percent of the river. Given this extraordinary degree of public ownership in a heavily urbanized area and the critical role that the riparian area plays for all fish and wildlife species in the Sammamish River Corridor, this Action Plan proposes to make improvement of riparian areas the major element of the strategic approach for restoration.

In the last decade, more than 20 projects have included replanting portions of the banks of the Sammamish River through the initiative of local governments, the Corps and literally thousands of volunteers. The Action Plan recommends a dramatic expansion of this work, applying a number of important lessons learned, including:

- In all cases, except where the county sewer line prohibits, the river's banks should be regraded to significantly decrease slope[12] before additional planting efforts occur. This should frequently include creation of flood benches set at or below the ordinary high water mark of the river. The benches should extend into the river's existing channel, constricting low flows while still providing an increase in total flood conveyance capacity. Juvenile salmon in the river have shown a preference for shallow water habitat and for cover that increases their safety from potential predators (Jeanes and Hilgert 2001). Flatter slopes and flood benches also provide more suitable conditions for native riparian and wetland plants to establish themselves. Significant slope regrading increases the likelihood that root systems of non-native species currently established on the river's banks would be removed, reducing their ability to compete with new plantings. Poor soil conditions should be improved throughout the planting areas, not just in the planting holes prepared for individual plants.
- Colonizing species (such as red alder, willow, redstem dogwood, and black cottonwood) should be the first species planted because they create a shade canopy relatively quickly and are effective competitors against undesirable invasive species, such as reed canary grass and blackberry . Survival rates for Douglas fir, vine maple, Sitka spruce, Nootka rose, salmonberry, Oregon grape, and ocean spray have been greater than 80 percent at past plantings along the Sammamish River. The goal should be to eventually establish a mixed conifer/deciduous forested zone (i.e. red cedar, cottonwood, Oregon ash). Conifers should dominate near the tops of banks—their greater height will provide maximum shade even with more gently sloped banks; they can better compete with blackberry (which are dormant less of the year than deciduous trees) along the vulnerable edges of the riparian corridor; and tend to cause fewer safety problems for users of the Sammamish River Trail. Willows on flood benches not only can grow quickly to provide significant shade, but also over time, can provide smaller woody debris that juvenile salmon appear to find attractive in the Sammamish River (E. Jeanes, R2, pers. comm. 2001). Migrating adult salmon have also been found to hold in area of the Sammamish River where willows provide cover.

[12] The existing slope of the banks varies from 1.5H:1V to 3H:1V, as designed for the 1964 channel improvements. However, the slope below the ordinary water line is often even steeper as a result of bank scour. This existing slope provides minimal habitat for juvenile salmon and minimizes the area which could be revegetated with riparian species. Sloping the banks back to a minimum of 3:1 (and up to 7:1 where there is room), including below the water level would provide additional fish habitat and a better riparian buffer.

- Aggressive maintenance for a minimum of three to five years after planting, particularly removal of invasive species and irrigation, is necessary for plants to thrive and should be included in all project budgets.
- Volunteers can be very helpful with major planting projects, as well as ongoing maintenance of planting sites. However, qualified technical experts should supervise volunteer planting projects to ensure appropriate plantings are conducted. Volunteers involved with ongoing maintenance can provide helpful advice for future plantings, in addition to serving as important public advocates for the river. Effective volunteers require coordination and appropriate training and tools—they are not free. Volunteers alone are not sufficient for the enormous task of replanting riparian areas along the entire river, and would not be appropriate in large-scale sites or where other activities such as grading are occurring. Construction crews and landscapers with adequate equipment are necessary in many cases to accomplish the scale of restoration envisioned in this plan.

In general, replanting efforts in the upper reaches of the river would likely provide the greatest benefit to salmon. In regard to shade, this is true both because the upper river reaches tends to be warmest (and therefore in most need of shade) and also because the benefits of shade are cumulative. As such, the further upstream shade is provided, the greater length of river is benefited. Jeanes and Hilgert (2001) indicate juvenile salmon spend a short period of time (days or at the most a month) in the upper river, after which they appear to migrate fairly quickly to Lake Washington (although this could also be due to a lack of habitat in the lower river). This would also tend to raise the priority of improvements in Reaches 5 and 6, as well as immediately downstream of major tributaries in the other reaches (i.e., Little Bear, North and Swamp Creeks).

In contrast to some suggestions, there does not appear to be an advantage to planting the west bank rather than the east bank of the river to block afternoon sun. Solar radiation heats the water throughout the day. Further, it is unlikely that mature vegetation present in a fairly narrow riparian corridor would reduce localized afternoon air temperature significantly enough to influence river temperature. It could even be argued that planting on the east bank would be preferable, because it would block solar radiation in the morning, and this would potentially help maintain cooler evening temperatures longer into the day. Updates of the model developed by King County to predict river temperature under different conditions may help refine priorities for sequencing riparian improvements. However, the fundamental strategy should be to plant both sides as soon as possible, in conjunction with regrading of riverbanks and the channel improvements discussed below. In addition to increasing shade and habitat for juvenile salmon, riparian improvements throughout the river are important as sources of detritus and insects (supporting the aquatic food web), LWD recruitment for habitat complexity, overhanging vegetation and cover, bank stability, and filtration of pollutants.

Wildlife species will also benefit significantly from restoration of forested riparian areas. Numerous species depend on riparian habitat during key stages of their life history. Native amphibians in particular, use riparian forests and downed logs for cover, foraging and wintering as juveniles and adults, though most return to aquatic habitats to lay their eggs underwater. Many bird species use riparian forests and shrubs, particularly where snags are abundant for nesting, foraging and perching. These include, but are not limited to bald eagle, great blue heron, green heron, osprey, kingfisher, wood duck, willow flycatcher, tree swallow, yellow warbler, and Swainson’s thrush. Both small and large mammals and numerous amphibians and birds also use riparian corridors for transit between habitats, making it strategically important to connect restored riparian areas to existing good-quality upland habitats. Relatively large forested wetlands and riparian areas in Marymoor Park are currently isolated from downstream areas. The Bear and Little Bear Creek basins also contain significant high-quality forest habitat that is currently isolated from the Sammamish River. Specific areas to target riparian improvement to benefit wildlife include Reach 6, to connect Lake Sammamish habitat with the Sammamish River and Bear Creek; the confluence areas of major tributaries, to improve connection between upland forest habitat and the Sammamish River; Reach 3, to connect existing wetlands to the river; and throughout Reach 4, where there is currently virtually no cover.

As noted above, one of the greatest assets of the Sammamish River is the degree to which its riparian areas are already in public ownership. King County Parks is by far the largest owner, managing the Sammamish River Trail, an undeveloped trail right-of-way on much of the river's left (west) bank, and numerous adjacent parks and open space lands. A new soft-surface trail, which would serve pedestrians and equestrians, is planned for the undeveloped right-of-way and would reduce conflicts between the growing numbers of users of the existing trail, which has nearly tripled since it opened in the mid-1970s. Design of the new trail has not yet been funded, but its construction would create an excellent opportunity for cost-sharing joint riparian improvements along the upper 11 miles of the river from Marymoor Park to Blyth Park in Bothell. Redmond's RiverWalk provides another excellent opportunity for riparian improvements along the river in the next few years. All riparian planting projects should allow for specific public access locations and viewpoints to encourage community buy-in and direct users to designated access points, rather than causing disturbance of riparian plantings. Chapter 4 identifies additional remaining opportunities for public acquisition of riparian areas along the river.

Privately owned riparian areas along the river should also be improved where feasible. Literature reviews of riparian buffer functions generally recommend that 100 feet is the minimum buffer width to provide a multitude of functions such as sediment retention, pollutant removal, shading, and wildlife habitat (Wenger 1999). Buffers wider than 100 feet would provide for increased functioning; however, due to the level of development currently present in the corridor, a minimum of 100-foot buffers are recommended. As discussed further in Chapter 4, improvements in sensitive area regulations for all jurisdictions should require buffers of at least 100 feet for new development along the Sammamish River and all its perennial tributaries to maintain and restore water quality (temperature) and improve fish and wildlife habitat. These sensitive area regulations should also be re-evaluated to provide incentives for already developed sites with narrower buffers to either move toward this preferred buffer width or at least improve the quality of existing buffers by providing native trees and removing non-native species such as blackberry. Incentives could include tax reductions for implementing native buffers, use of buffer averaging on individual parcels to allow enhancements in buffer quality and width in some areas with reduced width buffers required in other areas, technical assistance or donations of native plants in exchange for specific types of improvements and maintenance of those improvements.

CREATE AND ENHANCE POOLS IN THE RIVER CHANNEL

As discussed in Chapter 2, dredging of the Sammamish River in the 1960s not only severely degraded riparian areas, but also changed the river channel to a generally uniform width and gradient. Maintenance for flood control has prevented development of channel variation that might otherwise have occurred naturally (such as recruitment of LWD). A remarkable 98.2% of the river is glide habitat, 1.4% is riffle and only 0.4% meets TFW criteria for pools (Jeanes and Hilgert 1999). Field tracking of adult chinook salmon migrating through the river in 1998 and 1999, found a clear preference for deeper areas with cover, even if the extra depth was minimal compared to average channel depth (K. Fresh, WDFW, pers. comm. 2001 and D. Houck, King County, pers. comm. 2002). Given the severe shortage of pools, and the clear preference that salmon have shown for deeper areas (for either thermal refuge or cover), creation of more and better pools throughout the river is a high priority of the Action Plan. Strategic considerations for how and where these pools should be created include the following:

- Pools should take advantage of existing sources of cool water wherever possible, including tributaries and groundwater inflows. Locations just downstream of tributary mouths should be a priority, if they can be designed so they do not fill with sediment. Groundwater studies currently being conducted by King County should help identify general areas of groundwater flow into the river; piezometers should be used to identify specific locations and elevations. In the Norway Hill area of Reach 2 and possibly elsewhere, some springwater or groundwater flows are piped directly to the river. New pools could be strategically located to take advantage of these inflows. King County is also investigating methods to reduce infiltration of groundwater into their sewer system.

- New pools and improvements to existing deeper areas should be constructed so they are self-sustained over time by river hydraulics. LWD can be used to create areas of localized scour, to inhibit mixing of cool water input with warmer river, and to provide cover to make pools more attractive to salmon. Most of the existing deeper areas in the river are located on the outside of meander bends, where the river naturally scours the bed and bank. These could be excavated deeper and supported with woody debris.
- New pools should be created in areas where there are currently long gaps between deep areas, including between RM 0.8 and 2.3, RM 3.9 and 5.6, RM 6.1 and 7.1, and RM 7.5 and 9.0. Assuming pools will primarily serve as thermal refuge, they are more important in the upper river, where temperature is generally higher, but given the severe overall shortage of pools, they are needed throughout the river's length.
- Pool improvement should be closely monitored in comparison to each other, as well as to baseline conditions and to unimproved deeper areas, to see what features appear to provide the most benefit for adaptive use in future projects.
- We do not recommend adding gravel to pool locations and other channel improvements, particularly if it will not be kept scoured clean by flow. It could be used in areas such as immediately downstream of tributaries, where it would naturally tend to accumulate, or experimentally to create pool tailouts and riffles (primarily in the upper river).

As discussed above, when riparian areas are regraded, existing slopes can be extended into the river to constrict the low-flow channel. Benches should be set at or below the ordinary high water mark so there is substantial shallow habitat for juvenile salmon use during their migration to Lake Washington. Jeanes and Hilgert (2001) found juvenile salmon utilizing this habitat resulting from bank regrading more extensively than other sites in the river (see Figure 12). Though this sampling also suggests this habitat type may be more important in the upper river, where salmon from Bear Creek and Lake Sammamish appear to be acclimating to the river, these results may also be due to a lack of this habitat type downstream. Shallow habitat should be created in specific locations throughout the river and monitored to see which features and locations provide the greatest benefits. As an example, based on the observations of Jeanes and Hilgert (2001), it appears LWD plays a much less important role in creating habitat for juvenile salmon in the Sammamish River than it tends to elsewhere, probably due to the river's much slower current (see Figures 13 and 14 for differences between shallow water zones with and without LWD). This does not mean LWD should not be used in projects on the Sammamish River, but it may be more effective if used in smaller quantities and in different ways than is typically optimal elsewhere. For example, more small woody debris (less than 12 inches in diameter and branches) could be utilized to increase cover density for small fish and reduce use of this habitat by larger potential predators. Woody debris is also particularly beneficial for amphibians and reptiles.

As discussed in Chapters 1 and 2, the length of the Sammamish River has been dramatically decreased from its historic condition, particularly through Reach 4, where it once meandered across the mile-wide Sammamish Valley. Though some have called for restoration of the old river channel or re-creation of meanders that at least attempt to emulate historic conditions wherever possible, the Action Plan does not recommend meanders of this scale. The historic river formed under watershed hydrologic conditions that had significantly higher surface water elevations throughout the corridor (because Lake Washington was 9 feet higher). Development in the corridor and watershed over the past century, particularly in its historic floodplain, has permanently altered much of the former hydrologic regime. The current channel also ranges from two to fifteen feet deeper than it did historically. It would be impossible to recreate the river's historic meanders, even if its channel was shifted to the few remaining meander locations. Under current conditions, adding large meanders to the river might further slow the river's flow, resulting in increased heating from solar radiation, although riparian restoration would tend to reduce this problem.

Redmond's RiverWalk has introduced small meanders of approximately one channel width to a portion of Reach 5, upstream of the NE 90th Street Bridge. Though limited surveys of juvenile salmon (Jeanes and Hilgert 2001) found greater use of this site than control sites with no restoration, they did not find greater use than other shallow habitats that have been created along the river. RiverWalk's meanders have created more complexity within the channel and are beginning to form small riffles and pools. Over time, they should hydraulically help sustain some deeper areas that were created by the project, which have not yet been monitored for their use by migrating adult salmon. Movement of the river channel is expensive and may not be possible on the side of the river where King County's sewer line is located (primarily the east bank). Additional small meanders may be feasible and valuable, particularly to sustain pools. As riparian areas are regraded and channel improvements are made, new habitats should be monitored for use by juvenile and adult salmon and other wildlife to determine if there is sufficient benefit from addition of small meanders to justify their cost.

Changes to the morphology of the river channel will alter its conveyance capacity, as will regrading and re-vegetation of riparian areas. Given that the Action Plan recommends these changes along the entire river, conveyance capacity could be altered enough with implementation of this plan to affect water surface elevation from current conditions along portions of the river. This is an important design consideration for all future improvements to the river. We therefore recommend that King County and the Corps of Engineers update the existing hydraulic model (HEC-2 Sammamish River Backwater Model) to incorporate projected changes to the river's conveyance capacity associated with implementation of the Action Plan. Work on the updated model should be coordinated with other hydrologic models that King County is currently developing for the entire greater Lake Washington watershed.

EXPLORE ENGINEERED SOLUTIONS TO COOL THE RIVER UPSTREAM OF BEAR CREEK

Extensive temperature modeling conducted by King County (included as Appendix B, but not discussed in detail here) has shown that while riparian revegetation will help to cool the Sammamish River, it will have most benefit to the lower river because of the cumulative benefit that shading provides over the length of the river. Shading has very little effect on Reaches 5 and 6 because of the very warm outflow from Lake Sammamish, but as shading occurs over the length of the river, moving downstream, the cumulative effect of reduced heating and some cooling provides significant cooling to the lower river. Table 5 shows the percent change in the average daily degree-days of thermal stress[13] for salmon for various restoration options.

[13] The index of thermal stress used in this modeling effort is described in more detail in Appendix B. In general, the index measures temperatures above 17°C which was used as a temperature above which salmon would experience stress or physiological problems. Although there are many studies which show some stress for salmonids at temperatures above 15°C, we used 17°C as the threshold where there would almost certainly be physiological stress or behavior modifications, particularly to populations that may be adapted to somewhat warmer temperatures that occurred naturally in the river.

Table 5. Summary of percent (%) change of average temperature stress for selected restoration options compared to the existing conditions.

(Adapted from Table 7 in Appendix B, does not include all alternatives modeled, please refer to Appendix B for detailed description of alternatives). Negative numbers indicate a decrease in temperature stress and positive numbers indicate an increase in temperature stress.

Alternative	Reach 6	Reach 5	Reach 4	Reach 3	Reach 2	Reach 1
Existing Condition (assumed 5 cfs surface withdrawals and 5 cfs groundwater withdrawals for modeling purposes; not based on actual data)	0	0	0	0	0	0
50% Shade	-0.9	-7.1	-41.6	-65.7	-84.1	-46.9
25% Shade	-0.4	-3.6	-21.6	-35.9	-51.6	-20.0
Eliminate Assumed Surface and Groundwater Withdrawals	-1.6	-5.4	-13.9	-17.1	+6.6	+5.0
Groundwater Augmentation (15 cfs @ 13° C)	-5.1	-16.2	-39.3	-45.6	-16.4	+4.6
Bear Creek Flow Restoration (5 cfs)	-0.1	-12.5	-6.4	-6.5	+6.2	+2.8
Lost Shading in Bear Creek Which Increases Water Temp by 2° C	0	+13.9	+8.9	+7.4	+4.3	+0.5
Combine Eliminate Withdrawals with Groundwater Augmentation (above)	-6.6	-20.8	-46.5	-54.9	-27.4	+7.5
Combine Eliminate Withdrawals with Groundwater Augmentation and Bear Creek Flow Restoration	-6.7	-29.8	-47.9	-56.9	-31.8	+9.0
Hypolimnetic Withdrawal (20 cfs)	-96.5	-92.8	-79.8	-76.1	-55.6	-11.3

The hypolimnetic withdrawal alternative is an option that would withdraw cool water from the hypolimnion[14] of Lake Sammamish and discharge it near the weir where it would be mixed with Lake Sammamish outflow to significantly reduce temperature of the river at its upper end. As shown by the model results in Table 5, this alternative could significantly reduce water temperatures in Reach 6, upstream of Bear Creek, where thermal stress for salmon is greatest. Historically, Bear Creek's confluence was approximately 0.7 miles (1.1 km) closer to Lake Sammamish, providing a cool water input. The other alternatives that were modeled can generally provide only minimal benefit in Reach 6. It is important to note, however, that without increased riparian shade, cooler inflow in Reach 6 would tend to heat up as the water moved downstream. Riparian improvements are important to address temperature conditions in the Sammamish River regardless of whether the outflow of Lake Sammamish can be cooled.

[14] During the summer months the lake is thermally stratified, with a layer of warm water at the surface (epilimnion) and a layer of cool water at the bottom (hypolimnion). Between the two is the metalimnion, a transition layer between the two. For modeling purposes, it was assumed that hypolimnetic water would vary in temperature based on monitoring data from King County.

The use of hypolimnetic withdrawal as a method for reducing temperature would be a highly engineered solution to the temperature problems in Reaches 5 and 6. Such a strategy has a variety of practical obstacles and potential ecological risks. It would require laying a pipe up to two miles in length to reach water at a depth below the lake's thermocline, where temperature is significantly cooler than surface waters. It would be necessary to design the intake structure to avoid causing localized problems for kokanee and other fish in Lake Sammamish. Removal of cold water from the lake could possibly alter the temperature stratification regime in the lake, and potentially cause adverse effects to the aquatic food web. Dissolved oxygen levels are typically very low (~1-3 mg/L) at this depth, therefore, aeration may be necessary before or during discharge. Phosphorus levels, in contrast, tend to be higher in the hypolimnion, which suggests this strategy could potentially lead to an increase in phosphorus loading to the river and Lake Washington; these conditions could possibly result in increased productivity and excess production of algae. This could, in turn, potentially result in lower dissolved oxygen levels in the river, as the algae die and consumes oxygen through decay. Clearly, more evaluation of these issues is required to better understand the feasibility of implementing such an option for reducing temperature in the Sammamish River. However, it would likely only need to be operated during the warmest months (August and September), so operation costs would be fairly low.

Another potential engineered solution is the use of cooling tower technology, which uses evaporation to cool water prior to discharge. Cooling towers use evaporative cooling to reduce the temperature of water prior to discharge. Cooling towers could be located adjacent to the river, near the intake and discharge points, eliminating the need for a long pipe to withdraw lake water. Similar to the hypolimnetic withdrawal, it would only be necessary to operate the cooling tower(s) during the time of year when cooler water would provide a benefit to migrating adult salmon--typically August and September. Ambient air temperature and humidity level however, limit the degree of cooling that can be accomplished with this process; cooling towers may be of limited benefit when air and water temperatures are highest (in the summertime).

These potential engineered options to address the temperature problem in the upper river should be investigated in greater detail prior to making a decision on whether such a solution is feasible from both an environmental and economic standpoint. However, because engineered solutions appear to be the only options for significant temperature reduction in the upper river a feasibility evaluation of these options is a high priority.

PROTECT ALL MAJOR TRIBUTARIES TO THE RIVER: BEAR, LITTLE BEAR, SWAMP AND NORTH CREEKS

The major tributaries to the river (Bear, Little Bear, Swamp, and North Creeks) provide significant cooling inflows to the river and have helped maintain the ecological functions that still remain. The confluences of these tributaries with the mainstem river are also significant nodes of fish and wildlife usage. The tributaries also provide significant spawning and rearing habitat for salmon species and are the destination for many fish that use the corridor. As shown in Table 5 even minor changes in flow volume and water temperature in Bear Creek can have fairly significant effects on water temperature in the upper river. One scenario analyzed in the model indicates that an increase of approximately 5 cfs in Bear Creek's summer base flow could significantly reduce thermal stress for salmon in the river--particularly in Reach 5, immediately downstream of Bear Creek's confluence with the river. The City of Redmond; the water districts of Olympic View, Northeast Sammamish, and Union Hill; and the Sahalee and Bear Creek Golf Courses withdraw the largest water volumes from the Bear Creek basin. Based on 1994 withdrawals, a 30 percent reduction in summer irrigation (assuming no change in year-round baseflow withdrawals) by these users could potentially increase flow in Bear Creek up to 2 cfs (D. Hartley, King County, pers. comm. 2001). Water conservation and/or replacement/augmentation of irrigation withdrawals with reclaimed wastewater in the Bear Creek basin could potentially increase flow by several cfs. Compared to historical conditions, Little Bear, Swamp, and North Creeks currently experience higher base flow conditions because of the use of imported water (from Cedar and Tolt basins) for irrigation of lawns and gardens (WRIA-8 Technical Subcommittee 2001).

However, there are still ground and surface water withdrawals from these sub-basins, which could be replaced with other water sources such as reclaimed wastewater to help protect and maintain sufficient flow volumes in these tributaries.

Groundwater recharge has been reduced in all of these sub-basins due to development and increase of impervious surface area. Base flows in Bear Creek are approximately 39% less than historic base flow conditions; approximately 26% of this change is associated with water withdrawal and 13% from loss of groundwater recharge due to increasing impervious surface area (WRIA-8 Technical Subcommittee 2001). In the Swamp and North Creek sub-basins, it is likely that a more significant loss associated with decreased groundwater recharge has occurred. We recommend water conservation measures, replacement/augmentation of irrigation withdrawals with reclaimed wastewater, and investigation of sites that may be suitable for groundwater recharge (either from floodplain reconnection or percolation of stormwater runoff) in all of the major tributary sub-basins.

Another scenario analyzed in the model evaluated the potential effects of increasing the temperature of Bear Creek inflow by 2° C[15]. An increase in Bear Creek inflow temperature would have a significant effect on mainstem river temperature, particularly in Reach 5. Similar effects could be expected for the other tributaries if riparian shading is reduced. It is therefore critical to maintain cool tributary temperatures by maintaining riparian cover in these sub-basins. Swamp Creek is highly urbanized, and as such, there may be areas of the mainstem river that experience significant heating. It may, however, be possible to decrease the level of heating (for example, if a reach was highly confined between developed areas and devoid of riparian vegetation and lined with rock or similar engineered erosion control features collect and retain heat some simple riparian revegetation or removal of rock could have a significant impact on temperature reduction). We recommend evaluation of the temperature regime in these four tributaries to determine if additional restoration efforts to improve and maintain riparian shading would be effective in further reducing temperatures.

Lastly, the confluence areas for all these tributaries are important habitat for fish and wildlife. The deltas at Bear and Little Bear Creeks have formed small riffles, which are used for spawning by kokanee or residualized sockeye. Additionally, these are natural areas for accumulation of LWD and small woody debris. They are also important holding areas for adult fish migrating upstream because of their cool water inflow. In addition, they also provide an important connection for wildlife between the Sammamish River and upland forest areas and wetlands in the sub-basins.

The confluence areas could be enhanced in a variety of ways, including creation of pools and LWD jams to allow a thermal refuge and reduce the immediate mixing of cool inflow water with warmer Sammamish River water. LWD jams could promote formation and maintenance of scour pools and further create channel diversity through sediment deposition in riffles and bars. To maintain the cooling effects of the tributaries, it is important to provide shading along the river downstream of the confluences.

APPLY MONITORING AND ADAPTIVE MANAGEMENT SYSTEMATICALLY ACROSS JURISDICTIONS

Even though the region has considerable experience with implementation of riparian improvements, this and other strategies recommended in the Action Plan should be pursued with a research and adaptive management approach. In recent years, a few studies have been conducted on adult chinook migration and juvenile use of various habitats (Fresh *et al* 1999; Jeanes and Hilgert 2001), however, there are still many unknowns regarding the most effective ways to improve aquatic habitat for all salmon species in the corridor. Historic conditions are only a minimal guide for habitat improvements in the river corridor, given

[15] An increase of 2° C was selected for modeling purposes assuming that is a reasonable increase in water temperature from decreased shading along a significant stretch of the creek. Not based on any water quality sampling data.

how severely it has been altered, and the inability to restore many of the processes that historically formed and sustained its ecological integrity. The fact that past alterations have severely degraded riparian and in-channel conditions in ways that are relatively uniform across the river's length can be seen as an opportunity for a restoration program. The entire river corridor cannot be restored all at once. As restoration projects are implemented in different areas, they can be treated to some extent as "experiments" and monitored to determine which methods are most effective and whether certain methods are more effective in some places than others.

The adaptive management approach as envisioned in this plan (see Chapter 5 for more detailed discussion), would not necessarily be directly tied to individual project sites, but should be incorporated into a larger river wide focus. Funds from individual projects should be allocated for this larger monitoring program. This will allow much more information to be gathered than could be reasonably funded by an individual project and will also provide for population-level monitoring throughout the corridor that would not likely be detectable at a single site.

LOWER PRIORITY PROBLEMS

There are a number of other problems in the watershed that need to be addressed in order for the Corridor to function to its maximum capacity and sustain habitats over time. However, in general they are of lower priority in this strategic approach because they are not the major factors for decline for either fish or wildlife species in the Corridor. The following provides an over view of some of these problems.

Fish Passage Barriers

There are numerous fish passage barriers present in the corridor, primarily located on minor tributaries, either at their confluence with the Sammamish River or further upstream. Although many of these minor tributaries are also degraded, these barriers prevent fish from accessing potential spawning and rearing areas. Removal of fish passage barriers can be implemented relatively quickly as a relatively low-cost way to dramatically increase fish habitat. Removal of fish passage barriers will not solve the most urgent problems in the corridor, but should be considered a "medium" priority to provide a well-connected corridor. There have been some surveys of fish passage barriers conducted by various entities, however, a consistent methodology has not been used throughout the region. We recommend a survey with consistent methods be conducted throughout the corridor that can be used to prioritize barrier removal (see Chapter 5).

Water Quality (Other than Temperature)

In addition to the temperature issues and strategies discussed previously, there are other known water quality problems in the Sammamish River that may adversely affect fish, wildlife, and human use of the corridor. As previously indicated, the Sammamish River is on the 303(d) list for elevated fecal coliform bacteria levels, low dissolved oxygen, and pH. These issues will likely be partially addressed through the riparian restoration strategy and other engineered solutions for decreasing water temperature (particularly dissolved oxygen levels which are directly related to temperature) previously discussed. Currently, the source of fecal coliform bacteria is not known: possible sources include pet waste, waterfowl waste, or other animal waste. There is little opportunity for leaking septic systems to be a source of bacteria, as most of the watershed is connected to the wastewater system. Buffering runoff with riparian areas and wetlands is a potential option for reducing bacterial contamination. Best management practices can be implemented to reduce pet waste and other domestic animal waste, such as buffers along seasonal ditches and other locations of runoff, frequent removal of waste, and public education. Nuisance waterfowl populations can be reduced by increasing riparian vegetation along the river corridor and active programs to discourage geese and other resident waterfowl (egg addling, etc.).

An additional known, but not well studied, water quality problem is elevated turbidity levels following storms, and deposition of fine sediment in the tributary streams. Fine sediment is likely derived from stormwater runoff from roads, parking lots, and cleared areas including agricultural areas and construction sites. This problem will need to be addressed by improved erosion control practices and long-term monitoring and evaluation of turbidity levels and erosion control measures. In some cases, it may be most beneficial to tight-line stormwater runoff around construction sites to decrease turbidity. .

Toxicity was observed in some samples collected in fall 2001 for King County's assessment of sediment and water quality in the Sammamish River. The cause of this observed toxicity has not been identified. More study of this potential cause of toxicity and an evaluation of whether agricultural infiltration basins (wetlands) could reduce this problem are warranted.

Water Quantity

Low flow conditions in the river are primarily a concern for upstream adult salmon migration and effects on water temperature. However, low flows could also concentrate pollutants that are discharged. Summer and late fall low flows are decreased from historic conditions. This overall decrease is suspected to have occurred as a result of increased ground and surface water withdrawals and runoff from impervious or less pervious surfaces that reduces groundwater recharge. Of particular strategic interest, is the opportunity to increase groundwater recharge through creation or restoration of wetlands and use of reclaimed wastewater for percolation through wetlands into the groundwater table. Existing wetlands in the floodplain could be reconnected to the river to allow seasonal inundation and groundwater recharge. Areas with suitably permeable soils should be identified where percolation ponds could be installed to allow percolation of reclaimed wastewater. Much more information is required before any of these proposals could be implemented; see Chapter 5 for recommended studies evaluating groundwater.

Floodplain Habitat

Very little of the historic floodplain has the capacity to serve its historic functions. Lacustrine wetlands where the river connects with Lakes Sammamish and Washington still perform many important ecological functions, including habitat for wildlife, nutrient and sediment retention, and flood storage. These areas should be protected and enhanced with native vegetation. Reconnection of existing floodplain wetlands should also be pursued, particularly to benefit wildlife habitat and groundwater recharge. Care should be taken; however, not to enhance habitat that non-native predators of juvenile salmon and native amphibians would use (such as bullfrogs, bass and other species). Predators often prefer year-round warmwater ponds and sloughs, whereas seasonally inundated floodplains provide more natural habitat for native species. In the Agricultural Production District, one or more palustrine wetlands that are currently farmed or otherwise degraded could be restored with the potential to utilize portions of the sites as nurseries for producing a stock of native wetland plants to maintain viable farming activities and possibly support further wetland restoration projects in the basin.

Overall, the strategic approach outlined in this chapter will address the worst problems in the Sammamish River Corridor: elevated water temperature and lack of aquatic and riparian habitat diversity. By rectifying these problems, the Sammamish River Corridor can begin to function again as a healthy migratory corridor for both fish and wildlife species. While we recognize the corridor will not be fully restored, it will however, be dramatically improved over existing conditions and serve as a strong link between habitats in the larger watershed. Then, as the most severe problems are addressed, other issues that are also contributing to the decline of fish and wildlife populations can be addressed. The next chapter will describe specific project and study recommendations to implement this strategic approach.

Figure 12. Catch per unit effort indices with standard deviation for setback levee test (shaded) and control (clear) survey sites in the Sammamish River, Washington, 2001.

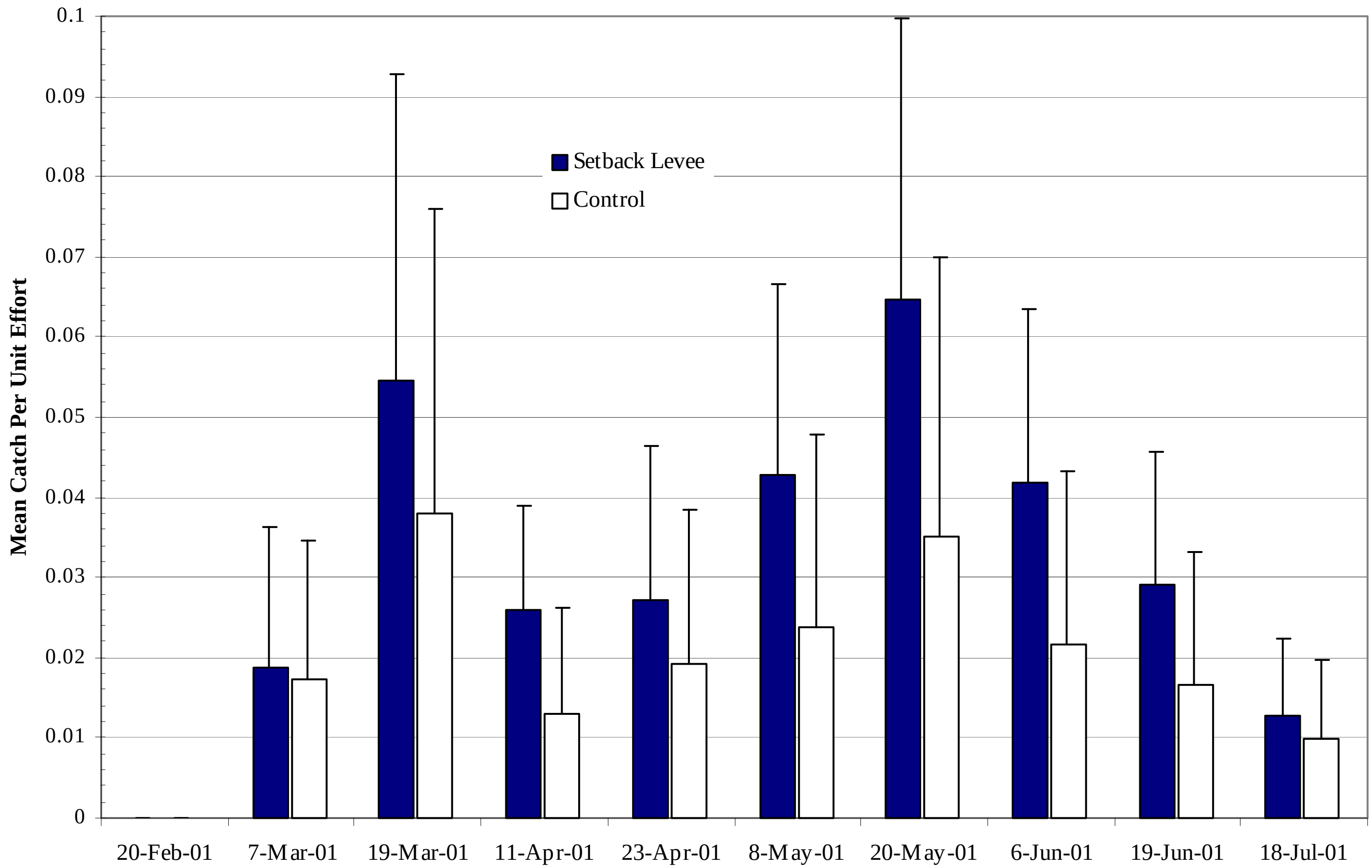

Figure 13. Catch per unit effort indices for large woody debris test (shaded) and control (clear) survey sites in the Sammamish River, Washington, 2001.

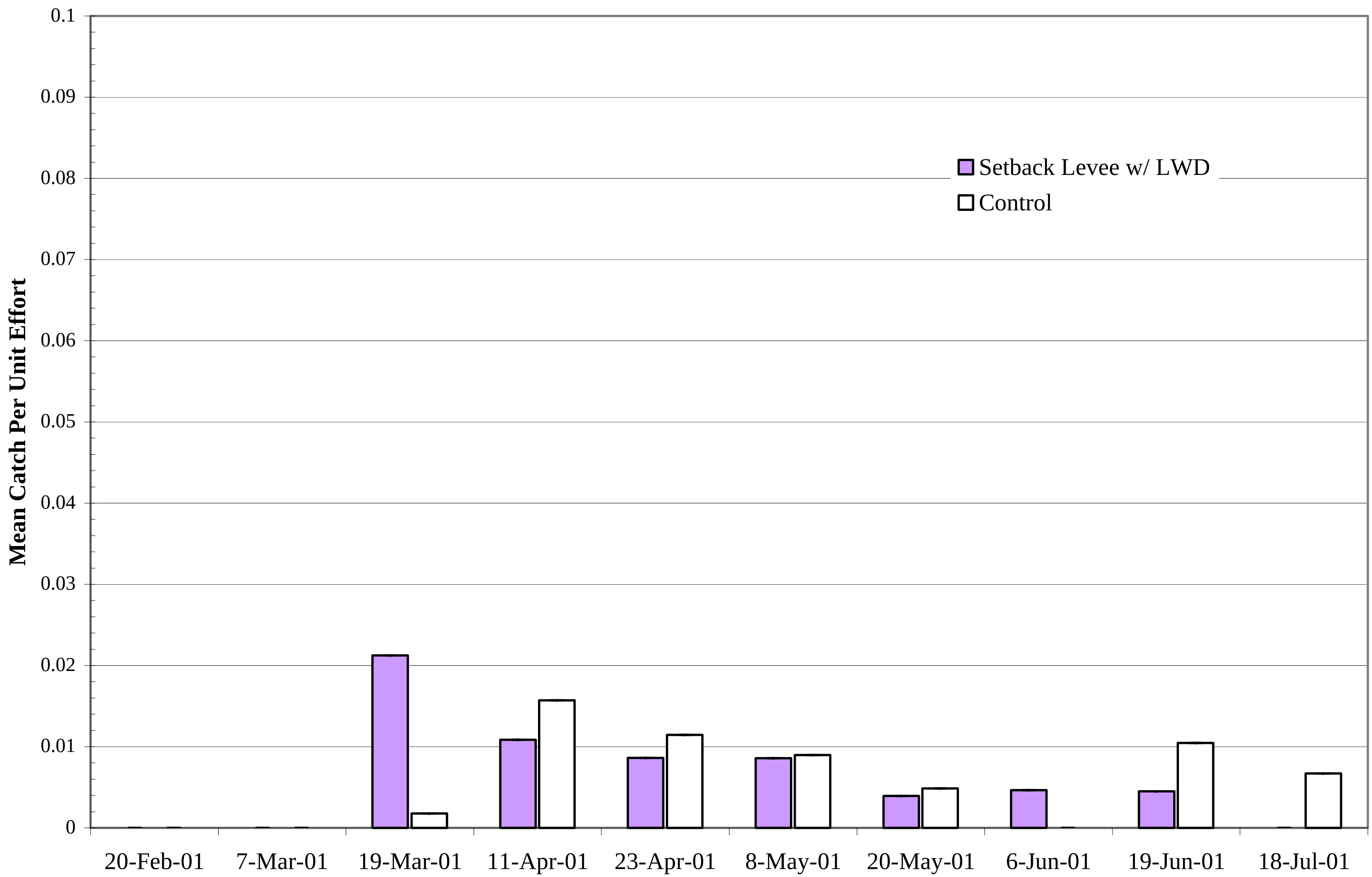

Figure 14. Catch per unit effort indices for setback levees, setback levees containing large woody debris, and large woody debris survey sites in the Sammamish River, Washington, 2001.

From Jeanes and Hilgert, 2001.